The Reinforcement and Inhibition

OF THE

Knee-Jerk.

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THE REINFORCEMENT AND INHIBITION OF THE KNEE-JERK.[1]

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Professor of Physiology, Harvard Medical School.

THE familiar fact that a blow upon the ligamentum patellæ causes a sudden contraction of the extensor muscles of the thigh became an object of careful physiological study when its diagnostic importance was pointed out by Erb and Westphal.

One of the most important additions to our knowledge of the phenomenon was made about two years ago by Drs. S. Weir Mitchell and Morris J. Lewis,[2] who, directing their attention to a phenomenon first pointed out by Jendrássik,[3] showed, in a series of carefully conducted experiments: (1) That the so-called knee-jerk can be increased by volitional acts directed to other parts of the body; (2) that volitional reinforcement lasts for an appreciable time after volition ceases; and (3) that continued violent muscular acts at last enfeeble the knee-jerk, and this enfeeblement lasts for an appreciable time.

These conclusions suggested the importance of studying the exact relations in time between the knee-jerk and the reinforcing act since we might reasonably hope to obtain in this way some insight into the nature of the mysterious processes having their seat in the central nervous system; and the object of this communication is to present to the Academy a preliminary report of the results of some experiments recently made in the physiological laboratory of the Harvard Medical School by Dr. J. W. Warren and myself with the hope of throwing light upon this subject.

[1] Reprinted from the Boston Medical and Surgical Journal, May 31, 1888.

[2] Physiological Studies of the Knee-Jerk, etc. The Medical News, Feb. 13 and 20, 1886.

[3] Deutsches Archiv für klinische Medicin, Vol. XXXIII, p. 175.

A detailed description of the apparatus used need not be given in this connection. Suffice it to say that the blow upon the ligamentum patellæ was delivered by a light hammer, (Fig. 1, H) fixed upon a splint-like covering enclosing the lower leg. By this arrangement a certainty that the hammer always struck the same point during each experiment was secured. The force of the blow was regulated by the tension of a spinal-spring S, which drew the hammer toward the knee when it was released by the breaking of an electric current controlling a magnet, M, also attached to the covering of the leg. The straps B B B served to secure the apparatus to the leg, and the rings L L to suspend the leg from the ceiling as shown in Fig. 2.

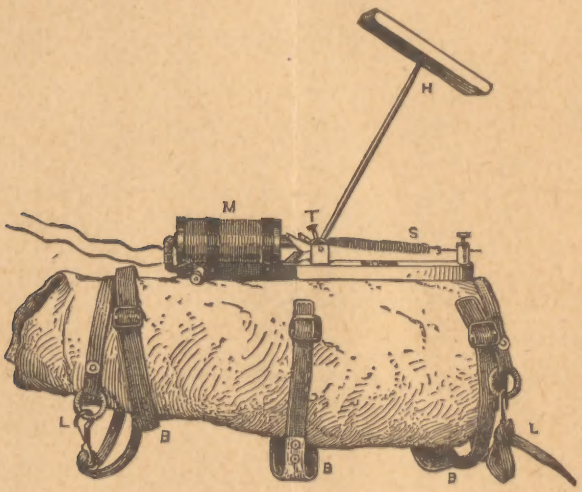

Figure 1.

The individual to be experimented upon lay upon his right side, with the left knee slightly bent (Fig. 2), and the internal condyle of the left femur resting upon a fixed support, the position being essentially the same as that adopted by Lombard.[4] The weight of the lower leg was borne by a cord hanging from the ceiling and fastened to the splint-like apparatus on the leg. The lower leg was thus free to swing in a horizontal plane round the knee-joint as a pivot, and its movement, reduced by a system of levers to one-sixth of its extent, was recorded by a pen (P) upon

[4] Is the "knee-kick," a reflex act? Am. Journ. of Med. Sciences, January, 1887.
The Variations of the Normal Knee-Jerk. The Am. Journal of Psychology, Vol. I, p. 1.

the smoked surface of a cylinder revolving once an hour. A pendulum myograph (D) served to break two electric circuits as it swung by striking against two keys adjustable at various points in its course. One of these circuits controlled the magnet holding up the hammer at the knee, and the other an electric bell (B), a stroke of which, on the breaking of the circuit, was the signal for the reinforcing act. Thus, by varying the position of the keys, it was possible to secure any desired interval from 0.0″ to 0.5″ between the reinforcing act and the knee-jerk. Where longer intervals were required, a pendulum vibrating more slowly than that shown in the figure was employed.

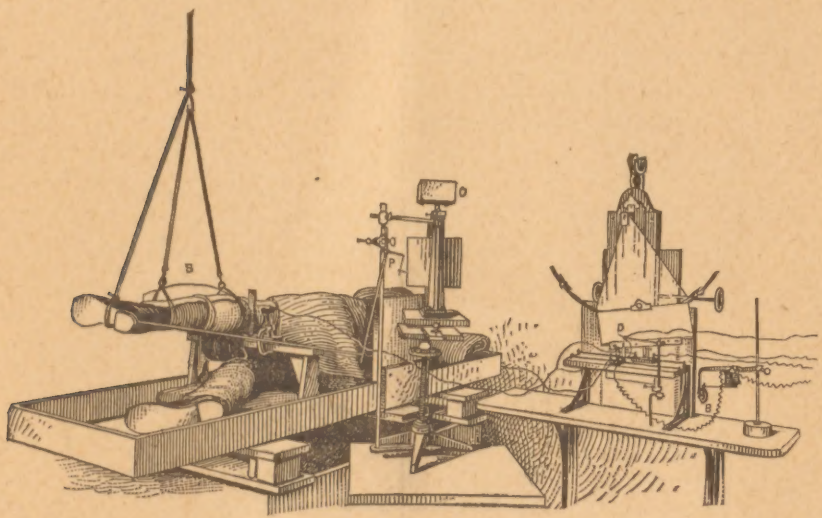

Figure 2.

The reinforcing act was a short, vigorous, clinching of the right hand upon a piece of wood, shaped somewhat like a tuning-fork, and furnished with metallic tips so adjusted that a slight pressure would bring them into contact, and thus close the same electric circuit that was opened when the bell was struck. As this circuit also included a Deprèz signal-magnet writing upon the smoked surface of the pendulum myograph, a record was obtained with each experiment of the reaction-time of the individual to an auditory impression.

This reaction-time, of course, includes a centripetal, a central, and a centrifugal portion, and as the total

duration was liable to considerable variation, and as, moreover, it was impossible to say in advance which portion of the reinforcing act would have the greatest influence upon the knee-jerk, it was decided to regard the stroke of the bell as the zero point of the reinforcing act, and when this point coincided in time with the blow of the hammer upon the ligamentum patellæ, the interval between the reinforcement and the knee-jerk was called zero. The object of the investigation was, therefore, to ascertain how the extent of the knee-jerk would be affected by varying the interval of time at which the blow upon the ligamentum patellæ followed the signal for reinforcement. No experiments were made in which the blow preceded the signal, since it would be difficult, after receiving the blow, to wait for the auditory signal before giving the reinforcing act.

Each experiment lasted, as a rule, about one hour. During this time several series of observations were made, each with a different interval between the bell-signal and the blow. Each series was divided into two portions, in the first of which there was no reinforcing act, and the knee-jerk was regarded as "normal," while in the second the individual responded to the bell-signal in the above-mentioned manner. The difference between the average extent of the knee-jerk in the first and second portion of each series was called the *special* reinforcement for the interval corresponding to that series, and the difference between the extent of the knee-jerk in the second portion of each series and in the first portion of *all* the series in the same experiment was called the *general* reinforcement for the same interval.

Experiments were made upon four different individuals with the same general results in each case. The nature of this result may be best understood by an examination of the curve shown in Figure 3, constructed from the record of 551 normal, and 624 reinforced knee-jerks in the same individuals. In this curve the abscissas represent the intervals between the bell signal and the blow, and the ordinates the difference between the "normal" and the re-inforced knee-jerks. Positive ordinates indicate an increase, negative a diminution of the knee-jerk. The figures at the left of the curve show in millimetres the absolute amount of increase or diminution. The dotted curve is the curve of *special* reinforcement; that is, it represents the average difference between the reinforced knee-jerk and the *special* normal of that series, while the full curve is the curve of *general* reinforcement represent-

ing the average difference between the reinforced knee-jerk and the general normal of the experiment. Both curves follow, it will be observed, the same general course, and show clearly that if the blow follows the signal at an interval not greater than 0.4″ the reinforcing act increases the extent of the knee-jerk. If the interval exceeds this amount a diminution

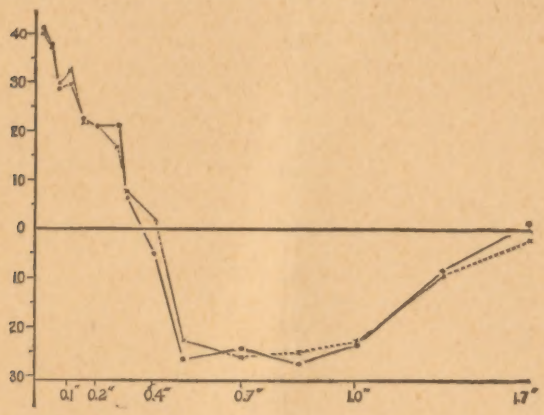

Figure 3.

of the knee-jerk results. If, however, the interval is prolonged to 1.7″ the reinforcing act is without effect upon the knee-jerk. To express the same conclusion in other words, we may say that, when by a brief act of volition the muscles of the forearm are innervated, the spinal cord is thrown into such a condition, that that portion of it which is concerned in the production of the knee-jerk is for a short time in a state of exalted activity which is succeeded by a period of depression and then by a slow return to the normal state.

We thus find the activity of one set of nerve centres serving first to exalt and then to depress the activity of a neighboring set. Without speculating upon the nature of the processes thus reacting upon each other it may be well to point out that we have in this alternating action a phenomenon which cannot fail to throw light upon the nature of "inhibition" and destined perhaps, when fully understood, to establish the interference theory on a firm basis.[5]

In this connection also, should be noted the observations of Meltzer on the inhibition of the peristaltic movements of the œsophagus by a rapid succession of movements of deglutition.

[5] Cf. Mitchell, op. cit., Reprint, p. 34.

It is evident that a wide field of research is open and that the various modes of activity of the central nervous system should be studied with reference to their effect upon the knee-jerk, and it is not too much to hope that careful experimental work directed on these lines will dispel a portion of the mystery which now surrounds the function of the nerve-cells.